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AUTHORITY

AFAL ltr, 17 Aug 1979

WADC TECHNICAL REPORT 53-436

COMPARISON TEST OF HIGH-ALTITUDE CAMERA

HOWARD L. ROSS

AERIAL RECONNAISSANCE LABORATORY

OCTOBER 1954

WRIGHT AIR DEVELOPMENT CENTER

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COMPARISON TEST OF HIGH-ALTITUDE CAMERA

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October 1954

RDO No. 683-28

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the Reconnaissance Charting Branch, Aerial Reconnaissance Laboratory, Directorate of Laboratories, Wright Air Development Center on Research and Development Order Number 683-28, "Comparative Camera Tests." The Corps of Engineers is participating in additional basic research under Corps of Engineers, Engineering Research and Development Laboratory Project Number 8-35-01-001. Mr. W. R. Allen, Mr. O. M. Minnich, Lt. J. C. Feldman, and Corporal H. L. Ross acted as projects engineers.

This report is a final report and will close out Research and Development Order Number 683-28.

The Photo Reconnaissance Laboratory herein referenced is presently title the Aerial Reconnaissance Laboratory

ABSTRACT

This report describes details of mapping trends from extremely high altitudes. Test photography was obtained to study whether the Air Force should utilize 6" focal length wide angle, 9" x 9" negative size photography or whether to utilize a longer focal length camera for basic coverage from altitudes of 40,000 feet or higher.

The Mapping and Charting Branch, Aerial Reconnaissance Laboratory, Directorate of Laboratories, this Center, conducted the Air Force portion of the project. The XT-6 Camera was the only Air Force camera which met necessary test requirements. The test photography was accomplished over the Chattanooga, Tennessee Test Area and at Ft. Sill, Oklahoma. Flight tests began in the latter part of 1946, and the final mission was accomplished in August 1951. No further flight tests can be performed with the XT-6 Camera due to its' mechanical condition. The Corps of Engineers performed the computational part of the research project at the Engineer Research and Development Laboratories, Ft. Belvoir, Virginia.

Corps of Engineer conclusions are:

A. That no apparent difference in definition appears in the T-5 and the XT-6 camera multiplex models; they do reveal that the XT-6 camera contact prints are superior to the T-5 camera contact prints.

B. Full exploitation of 12" focal length, 18" x 18" format photography might be necessary in order to justify the greatly increased operational difficulties in obtaining, processing and handling 12" focal length, 18" x 18" photography. A full change-over in compilation instruments might be necessary.

C. The increased definition in 12" focal length mapping photography would eliminate the need for additional 12" focal length coverage, but the requirements of 24" supplemental coverage for certain areas and altitudes would remain.

D. Future mapping trends should be constantly observed and when deemed expedient a 12" focal length, 18" x 18" camera with a precision, wide angle mapping lens should be developed.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

E. B. WOODFORD
Technical Director
Aerial Reconnaissance Laboratory

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INTRODUCTION

The advent of high speed, high altitude photo reconnaissance aircraft indicated that research into basic designs for suitable cameras, aircraft conditions, and allied equipment should be studied in order to determine optimum camera sizes, focal lengths, resolution factors and suitable allied equipment to be utilized in mapping from high altitude photography.

Headquarters, USAF, requested that the Aerial Reconnaissance Laboratory obtain sufficient comparison photography to enable the Corps of Engineers to conduct the directed study program.

SECTION I

Information received by Headquarters, USAF, from Chief of Engineers indicated that a possible solution to the problem of mapping from extremely high-altitude photography was in improving the quality of detail portrayed on the 9" x 9" negative using a 6" focal length wide angle lens rather than going to a longer focal length camera for basic coverage.

On 5 June 1946 USAF through Expenditure Order #683-28, T.I. 2124, Add #94 directed that comparative tests be conducted between the present 6" wide angle camera and a 12" wide angle camera. These tests were to be made at the highest altitude available.

SECTION II

The Fairchild XT-6 Camera (12" focal length, 18" x 18" negative size) (See Fig 1) was chosen to be compared with a precision mapping camera (T-5 6" focal length, 9" x 9" negative size). (See Fig 2). The XT-6 offered distinct advantages because its image size was double the image size of the 6" focal length camera while its area of ground coverage remained the same. The XT-6 camera was the only camera which met the 12" focal length, 18" x 18" negative size requirements. Serious problems faced the project engineer in that the XT-6 camera had been completely dismantled and had fallen in complete disrepair after previously being tested and disposed of. Upon return of the XT-6 camera to this station the camera lens had been removed. It was necessary to properly install a wide angle 12" focal length lens and repair the camera in a manner which met mapping camera requirements. With no engineering detail and scavenged parts the project engineer completely rebuilt the XT-6 and made it mechanically operable.

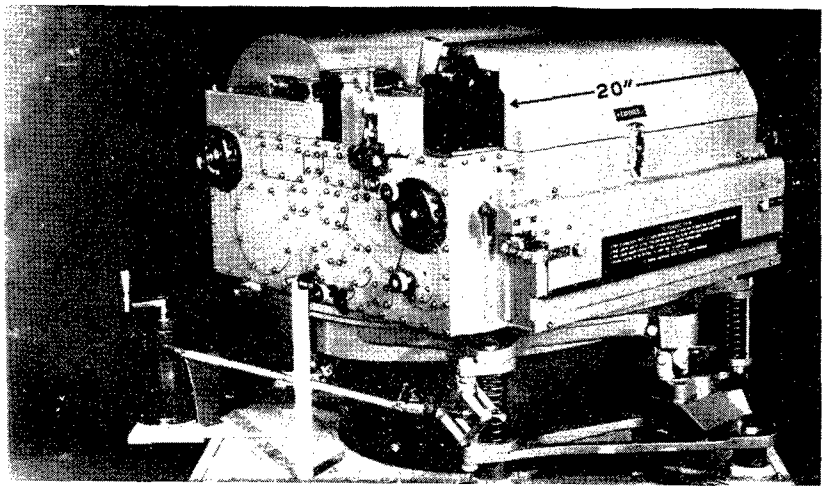

Fig. 1 Fairchild XT-6 Camera

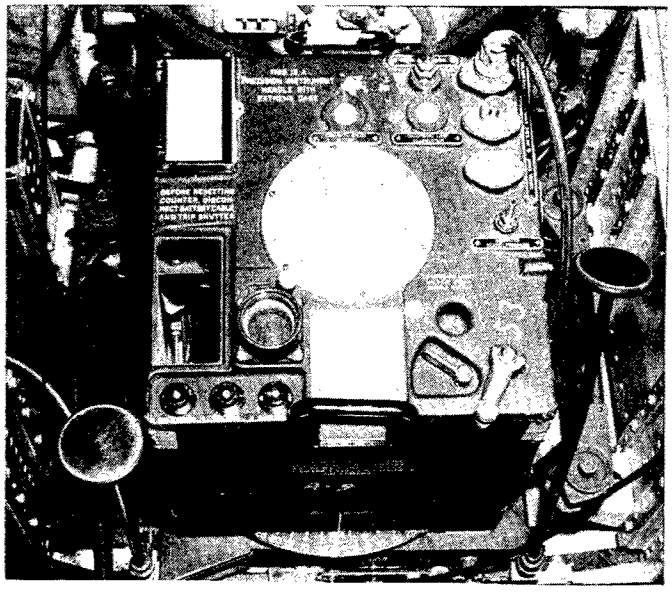

Fig. 2 T-5 Camera

SECTION III

Upon completion of basic mechanical repair of the XT-6 Camera the Fabrication Unit of the Photo Reconnaissance Laboratory Technical Services Branch, under the direction of the project engineer, installed the old and new Metrogon lens (Fig 3), fabricated special new spools, and built a new format frame. Fig 4 illustrates the original lens installed in the XT-6 camera. The new format frame was required because no film was currently being manufactured wider than 18". The new format frame had an opening of 17.5" x 18". This permitted utilization of available 18" film. The disturbance of the fiducial marks and the installation of the new lens necessitated collimation and calibration of the XT-6 Camera.

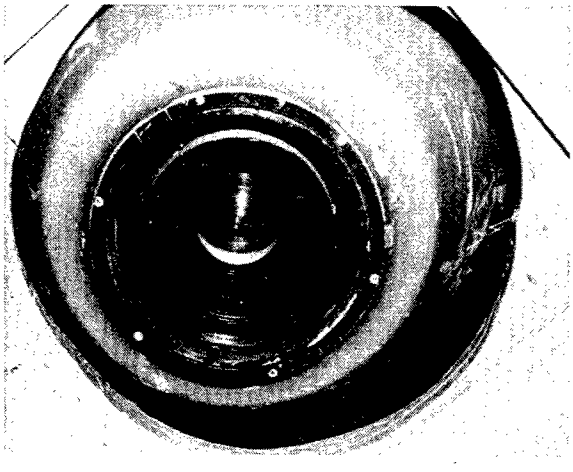

Fig. 3 New XT-6 Camera Lens

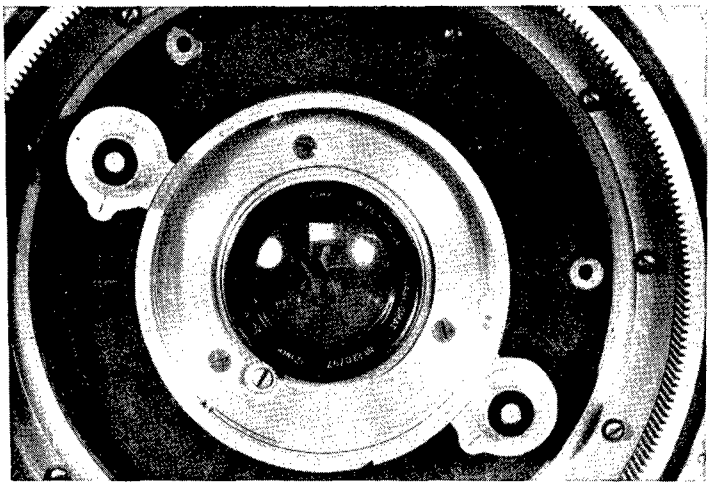

Fig. 4 Old XT-6 Camera Lens

AUTO-COLLIMATION OF THE XT-6 CAMERA

Generally speaking, there are two basic methods of collimating a camera. These methods are the Laboratory method and the field method. The Laboratory method was utilized and is described below. The Laboratory method is the easier of the two methods and is usually employed. It requires a stand or mount, a simple leveling table which has a hole near its center, a glass plate a little smaller than the focal plane space, a pan of mercury, a spirit level, and a light. (See Fig 5). The camera is placed on the leveling table with the lens immediately above the hole, the glass plate on the focal plane, and the pan of mercury directly below the lens. The glass plate should have a small cross drawn or etched near its center. This cross should be the intersection of two lines stretching across the plate at right angles to each other. (See Fig 6). It is necessary only to have the ends of these lines drawn on the plate. They serve to indicate the positions for the fiducial marks and will be registered on every negative obtained by the camera. The face of the glass on which the cross and other lines are drawn is turned down against the focal plane. The glass plate should be selected for flatness and uniform thickness and cut to the proper thickness to allow for slight shifting in the focal plane. The plate in place, the camera is leveled to bring the plate into a horizontal position. The cross is illuminated properly, the light being a little to one side and shifted until the image reflected from the mercury surface can be seen on the glass surface. The plate is shifted until the image coincides with the cross. The positions of lines at the focal plane frame are now marked on the frame with a sharp needle drawn along a straight edge. If fiducial marks have already been placed in the frame, the test will show whether or not they are correctly placed. A few trials of the light in different positions may be necessary before the observer is able to see the image of the cross. The closer the mercury is to the lens the brighter the image will be, but after a little practice it should be possible to catch an image with the mercury pan placed three or four feet below the lens. By

careful work the position of the principal point should be in error by not more than one tenth of a millimeter, ignoring the possibility of lens decentering.

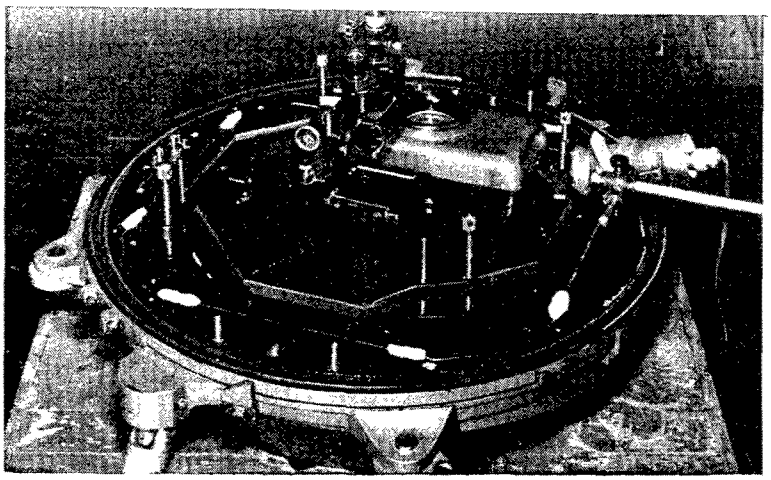

Fig. 5 XT-6 Camera Calibration

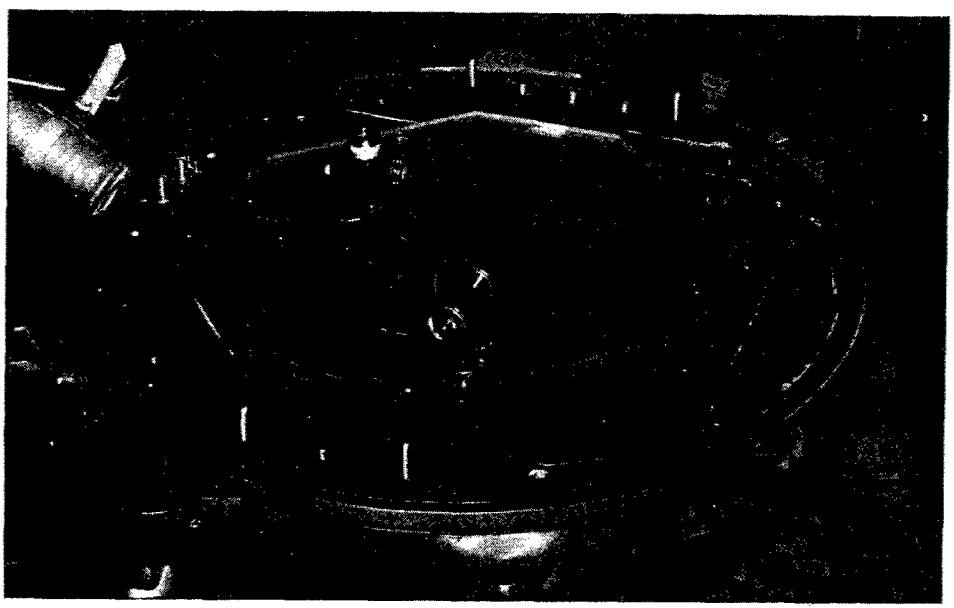

Fig. 6 XT-6 Camera Calibration

METHOD OF CALIBRATION

The calibration method utilized in calibrating the XT-6 camera is described in detail in Aerial Photographic Branch Project Report #91, dated 2 January 1946 prepared by the ERDL, Aerial Photographic Branch at Wright-Patterson Air Force Base. Film was used to make the exposures on the calibration range. Obtained results were corrected for film shrinkage by measuring the length of the diagonals of the focal plane frame directly on the camera and comparing these with like measurements on the exposed film. The film was measured on the Gaertner Comparator by cutting a diagonal strip 9" wide containing the target images from the 18" exposure frame.

The calibrated focal lengths as computed for the two diagonals were 304.04 mm and 303.87 mm. The maximum plus distortion was .25 mm at 205 mm or about 34° from the principal point, with an equal distortion at 45°. The distortion curve was very similar to that of a 6" metrogon lens at twice the scale.

It was concluded that a focal length of 303.95 mm and the other values obtained by this calibration are sufficiently accurate to be used in proposed camera comparison tests.

SECTION IV

The Corps of Engineers expressed a desire for the test photography to meet the following requirements.

Five flight lines covering the area between 84° and 85° - 30' W longitude; 35° and 35° - 30' N latitude (Chattanooga, Tennessee) was chosen as the desirable test area. The side lap should be 25% and the forward overlap 60% in order to assure stereoscopic coverage. The altitude to be as high as possible with a desired minimum of 40,000 feet.

The above area was chosen because of the high density of control installed by the Tennessee Valley Authority.

At least 8 missions were flown to fulfill the above request.

The original flight tests were performed in B-17 type aircraft with an open hatch for the XT-6 camera; other later missions were flown in a B-29 with the camera equipment installed in the bomb-bay racks. All missions failed due to weather, camera failure, or inability of the aircraft to reach the necessary 40,000 feet altitude.

The Flight Test Division placed a 35,000 feet ceiling on all suitable test aircraft when all engines of a B-29 failed at 36,000 feet and could not be started until an altitude of approximately 26,000 feet had been reached.

The Flight Test Division prohibited future missions on the basis that the life of the crew and the aircraft were endangered.

No further flights were attempted until an aircraft capable of obtaining 40,000 feet was acquired.

A high altitude photographic test aircraft (XR-12-002) was obtained.

Further tests in this aircraft were conducted but weather conditions in the area and camera failure prohibited a completely successful mission. Weather difficulties were later minimized by changing the photographic area. Aircraft difficulties were minimized with the XR-12 experimental aircraft.

One apparently successful mission was flown in the test aircraft and forwarded to the Corps of Engineers for compilation even though the vacuum back was photographed through the XT-6 camera film.

Multiplex evaluation of the T-5 precision mapping camera film disclosed that the camera system had failed in some manner as warpage could not be removed from the multiplex models. At this time, the experimental test aircraft crashed and was a total loss.

Major continuing difficulties were evaluated and were determined to be camera system failure; unsuitable photographic weather and aircraft trouble. To eliminate these difficulties, the controlled photographic area was changed to Western states, a new experimental test aircraft was obtained; the only major difficulty remaining was the XT-6 camera system.

SECTION V

Flight mission failures at extreme altitude indicated that major overhaul of the XT-6 camera system was necessary before operation at extreme test altitudes could be resumed.

A detailed study prepared by the project engineer disclosed the following discrepancies or inadequacies:

1. Conduct an engineering study and analysis of the XT-6 camera and evaluate extent of repairs necessary to insure reliable operation under all climatic conditions. (temperature range 120° F to 65° F).

2. To accomplish the above, it was mandatory that the following be examined and/or adjusted and/or replaced.

   a. The electrical wiring system.

   b. The intervalometer system.

   c. The motive force.

      (1) Two (2) twelve (12) volt motors reworked or preferably replaced with twenty-four (24) volt motors to increase torque as an aid to film transportation under adverse conditions. Constant running motor clutched in for cycling.

      (2) The gearing of the winding and tripping mechanism itself.

(3) The absolute wind and trip transfer systems.

(4) Remove or disconnect the clutch system.

3. A complete study and evaluation of the gearing, pinning, and spring system and slack originating in back of the above, along with a solution as to alleviating such slack.

4. A study of the cycle of operation and installation of proper mechanisms to insure same.

5. A more suitable mount or mounting arrangement.

6. A study of the vacuum system to insure proper vacuum supply with proper indication of same.

The Fairchild Camera and Instrument Corp. was awarded Contract AF33 (038) 9952 to study repairs necessary and to prepare a cost estimate on a second phase repair program.

Minor obvious internal mechanical and electrical repairs were made to the XT-6 camera upon disassembly for study. Numerous repairs were made to the electrical relay contacts at this time. Twelve volt wind motors were replaced with 24 volt motors which greatly increased produced torque.

The study report submitted concluded that a limited number of exposures could be made with the XT-6 camera if the camera compartment was adequately pressurized and heated.

Repair costs for a complete overhaul were judged to be excessive for the few photographs required. Project engineer, after consultation with all concerned, decided to fly the camera with minor repairs in another Republic Rainbow XR-12. No extended precision mapping missions could be flown with the XT-6 camera due to its' mechanical condition.

SECTION VI

The XT-6 camera was repaired and reassembled, and returned to the Photo Reconnaissance Laboratory. The Republic Rainbow XR-12 model number 003 was available by this time. The T-5, XT-6 and allied equipment was installed in the test aircraft and the complete system carefully ground checked. Weather conditions in the photographic area were carefully watched while the air crew remained on "stand-by".

The photo-navigator and air crew were briefed and the mission was "ready". On the morning of 15 August 1951 the project engineer decided that the mission should be flown.

Photo Reconnaissance Laboratory mission #226 was flown in the XR-12 aircraft over the Ft. Sill photographic area. The flight was airborne for 5-1/2 hours. Three flight lines were accomplished at 35 and 40,000 feet.

The mission was delayed at photographic altitude while waiting for proper light conditions. During this time the cold saturated the XT-6 and the text exposures had to be "wound through" by manual means even though the camera was in a heated and pressurized compartment. Approximately 100 feet of useable XT-6 film was obtained.

The test film was returned to Photo Reconnaissance Laboratory, carefully processed and viewed. The film was turned over to the Corps of Engineers Liaison Office at Wright Air Development Center when all preliminary tests indicated that the test film would fulfill the mission as requested by Headquarters, USAF.

SECTION VII

On 2 November 1951, the Corps of Engineers accepted the high altitude camera comparison test photographs. A study was conducted by the Corps of Engineers and the following are pertinent excerpts from their findings:

"Letter from Corps of Engineers, Washington 25, D.C. dated 8 December 1951

SUBJECT: 12 Inch Focal Length Wide Angle Mapping Camera

THRU: Assistant Chief of Staff, G-2, U.S. Army

ATTENTION: Chief, Map and Photo Branch, Training Division

TO: Chief of Staff, U. S. Air Force

1. Reference is made to 1st Indorsement dated 1 May 1946, file Speie (2 Apr 46), from Office of the Chief of Engineers to Assistant Chief of Staff, G-2, War Department, General Staff, Subject: "Development of High Altitudes Precision Mapping Camera", in which it was recommended that comparative mapping tests be made with the 6 inch wide-angle camera and a 12 inch wide-angle camera at approximately 50,000 feet altitude. Because of difficulties experienced by the Air Force in attempting to use the XT-6, and experimental 12 inch focal length wide-angle camera, for this purpose, these tests have not been successfully completed. Nevertheless, Air Force has been successful in obtaining a limited amount of simultaneous coverage with the T-5 and XT-6 cameras at an altitude of approximately 40,000 feet.

2. Since the experimental XT-6 camera does not have the high degree of precision required in a mapping camera, the comparative evaluation of this photography necessarily has been limited to a comparison of the definitions in contact prints and multiplex models. Although the limited tests show no apparent difference in the definition in the multiplex models, they reveal that the XT-6 prints are definitely superior in definition to the T-5 prints.

3. There are still many unknowns regarding the practical problems connected with the utilization of very high altitude photography for mapping.

Theoretical considerations indicate that it is not likely any significant improvement in mapping accuracy will be realized with a 12" mapping camera over that possible with a 6" focal length camera at altitudes up to 40,000 feet. However, superior definition in the 12" photography has been demonstrated and it may prove practicable and more efficient to use such a camera for both basic mapping and supplemental coverage at altitudes up to 40,000 feet in lieu of the currently acceptable 6" basic coverage with supplemental 12" focal length photography for detailed identification. . .

4. . . . . .consideration is being given to the development of a precision 12" wide-angle camera for this purpose. In order to meet possible mapping requirements, the format size of such a camera should be 18 x 18 inches rather than 9 x 18 inches. Furthermore, since the planigon lens (distortion free lens) has been found in tests to be superior to the Metrogon lens for mapping purposes, and will be supplied in the near future on the T-11 mapping cameras, it is believed that the design of the 12 inch camera should incorporate the planigon lens.

5. The Corps of Engineers is still interested in obtaining mapping photography at high altitudes with a suitable 12" wide-angle camera for test purposes and will concur in an Air Force project to develop a precision wide-angle mapping camera with 12" focal length planigon lens.

FOR THE CHIEF OF ENGINEERS:

/s/F. B. Hall, Jr.
F. B. HALL, JR.
Colonel, Corps of Engrs.
Chief, Engr. Intell. Div.
Military Operations "

"2d Ind from Hq, USAF, Washington 25, D.C. dated 10 January 1952

TO: Office of the Chief of Engineers, Department of the Army, Washington 25, D. C.

1. Full exploitation of 12" focal length, 18" x 18" format mapping photography might be necessary in order to justify the greatly increased operational difficulties (estimated to be 6-8 times that of 9 x 9 format) encountered in obtaining, processing, and handling this photography.

2. In order to fully exploit this photography a complete changeover in compilation instruments might be necessary.

3. The increased definition in the 12" mapping photography would eliminate the need for additional 12" coverage but the requirement for 24" or 26" supplemental coverage for certain areas and altitudes would still remain.

4. Further research by the Departments of the Army and the Air Force will certainly bring to light additional benefits that may be expected from a 12" focal length mapping camera and at the same time additional experience in the use of 18-1/2 inch film will lessen the operational difficulties encountered at present.

5. These trends will be watched closely and when it is deemed expedient the 12" focal length, 18" x 18" format camera project will be removed from the design study stage and development of a prototype will begin. A precision wide-angle mapping lens of the most advanced design will be incorporated in this camera.

FOR THE CHIEF OF STAFF:

/s/Paul T. Cooper for
W. W. HOLMES
Colonel, USAF
Chief, Equipment Division
Directorate of Research and Development
Office, Deputy Chief of Staff, Development"

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Bagley Aero-Photography and Aero-Surveying. Section 303, page 313.

Air Materiel Command Technical Instructions 2124-94, dated 5 June 1946, and letter from Commanding General, AAF, dated 29 May 1946, Subject: Development of High Altitude Precision Mapping Camera.

Letter from WD, Office of the Chief of Engineers, Washington, D.C. to Commanding General, USAF, Washington 25, D.C., dated 2 January 1947, Subject, Tests of 5.2 inch Aerial Photography.